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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Navy Department

INVESTIGATION OF THE TRIM CHARACTERISTICS OF A $\frac{1}{20}$-SCALE MODEL OF THE FLEETWINGS XBTK-1 AIRPLANE OVER A WIDE RANGE OF ANGLES OF ATTACK

By

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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INVESTIGATION OF THE TRIM CHARACTERISTICS OF A $\frac{1}{20}$-SCALE MODEL OF THE FLEETWINGS XBTK-1 AIRPLANE OVER A WIDE RANGE OF ANGLES OF ATTACK

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SUMMARY

Tests of a $\frac{1}{20}$-scale model of the Fleetwings XBTK-1 airplane have been performed in the Langley 15-foot free-spinning tunnel to determine the trim tendencies of the airplane at attitudes above the stall. The results of the tests indicated that the model would trim longitudinally only in the normal range of angles of attack and that the yaw trim tendencies for such longitudinal trim conditions were normal. Although wide oscillations in yaw were noted for some conditions, they occurred at angles of attack larger than those indicated as possible for longitudinal trim and spin equilibrium. It appears, therefore, that the oscillatory motions reported for the airplane may have been the direct result of control movements rather than the result of inherent oscillatory tendencies.

INTRODUCTION

During the stall tests of a Fleetwings XBTK-1 airplane in June 1946, performed by company pilots, some abnormal and highly undesirable airplane motions were obtained. The motions occurred after the pilot had attempted a stall: the airplane rolled abruptly to the left and then, remaining in a stalled attitude, oscillated in roll and yaw to the right and left. The airplane did not go into a spin but continued oscillating in roll and yaw despite the pilot's attempt to stop the motion. Moving the stick forward appeared to flatten the attitude of the airplane

[redacted]

whereas moving the stick back appeared to steepen the attitude. This occurred several times when the pilot attempted to pitch the airplane from its stalled attitude. A spin-recovery parachute was eventually used to damp the oscillations and pitch the airplane from its stalled attitude.

This unusual oscillatory behavior was not explained by the results of previous wind-tunnel investigations. Free-spinning tunnel tests of a $\frac{1}{20}$-scale model (reference 1) had indicated that the airplane should spin rather steeply and steadily and should recover from the spin quite rapidly when the controls were reversed. Tests of a powered model in the Langley 7- by 10-foot tunnel (references 2 and 3) had indicated no unusual characteristics and, in fact, had indicated a quite high degree of longitudinal and directional stability. In an attempt to determine the cause of the unusual oscillations at stalled attitudes, an investigation has been conducted in the Langley 15-foot free-spinning tunnel with the $\frac{1}{20}$-scale model of reference 1 so mounted as to have freedom first in yaw and then in pitch. The airplane propeller was not simulated. The results are presented herein.

SYMBOLS

$\bar{c}$ wing mean aerodynamic chord, feet

c local wing or horizontal tail chord, feet

δ_r rudder deflection (positive when trailing edge is to the left), degrees

δ_e elevator deflection (positive when trailing edge is down), degrees

δ_a aileron deflection (positive when trailing edge is down), degrees

α angle of attack of thrust line (positive when the nose is above the relative wind), degrees

ψ angle of yaw (positive when the nose of the airplane is to the right of the flight path), degrees

APPARATUS AND METHODS

The $\frac{1}{20}$-scale model of the Fleetwings XBTK-1 airplane used for the current tests was the same model that was previously used in an investigation of the spinning characteristics of the airplane (reference 1). The dimensional characteristics of the airplane are given in table I. A three-view drawing of the model is presented in figure 1.

For the investigation of the trim characteristics in pitch, the model was mounted at its center of gravity in such a manner as to be free to pitch about the stability Y-axis and fixed about the other two axes. For tests at different angles of yaw, the yaw angles were set by tilting the model mounting bracket about the stability Z-axis. At the test airspeed the model was displaced from its normal trimmed position and moved to various angles of attack in the stalled region by means of strings installed on the nose and tail of the model. The strings were attached in such a manner that when they were released their influence on the model was negligible. When the strings were released, observations and motion pictures were made to see if a trimmed condition existed above the stall. Photographs of the model mounted in the 15-foot free-spinning tunnel free to pitch are shown in figure 2.

To investigate the trim characteristics in yaw, the model was mounted free to yaw about the stability Z-axis and fixed about the X and Y axes. In these tests a range of angles of attack from unstalled to stalled attitudes were investigated by rotating the model about the stability Y-axis to various fixed settings. Observations were made and motion pictures were taken of the model motion and trim position when set at a given angle of attack for various control settings.

The stability axes, as used herein, are defined as an orthogonal system of axes in which the Z-axis is in the plane of symmetry and perpendicular to the relative wind, the X-axis is in the plane of symmetry and perpendicular to the Z-axis, and the Y-axis is perpendicular to the plane of symmetry.

PRECISION

The model test results presented are believed to be accurate within the following limits:

α, degree	±1
ψ, degree	±1
Center-of-gravity location, percent $\bar{c}$	±1

The controls were set with an accuracy of ±1°.

TEST CONDITIONS

The center-of-gravity location of the model was at 27.8 percent of the mean aerodynamic chord, approximately the same as the center-of-gravity location of the airplane when it encountered the aforementioned difficulties.

The yaw trim tests were made at angles of attack ranging from 0° to 54°. For the pitch trim tests, the model was set at a yaw angle of 0° and also at plus and minus yaw angles approximately equal to the extreme values of yaw obtained from the yaw-free tests.

Tests were made with the controls set from zero to the following maximum values possible on the airplane:

Rudder, degrees	30 right, 30 left
Elevator, degrees	25 up, 15 down
Ailerons, degrees	15 up, 15 down

The model was also tested with both ailerons 5° up because flight tests indicated that in stalled attitudes both ailerons tended to float up when the stick was neutral laterally. This floating tendency was caused by the fact that the ailerons were actuated through a spring-tab system with no direct tie between them. Tests with elevator deflections of 35° up and 20° down were also made.

For all tests reported herein the landing flaps were neutral, the landing gear was retracted, the dive brakes were closed, the cockpit was closed, and all external stores were removed from the wings. This model configuration simulates that of the airplane at the time trouble was encountered.

Subsequent to the time of the tests reported in reference 1, fixed slots were installed on the XBTK-1 airplane. These slots, however, were sealed at the time the reported difficulties were encountered and, therefore, slots were not simulated on the $\frac{1}{20}$-scale model for the current tests.

The tests were made at a dynamic pressure of 2.59 pounds per square foot. The test Reynolds number was about 117,500 based on the mean aerodynamic chord of the wing. The turbulence factor of the tunnel is 1.78.

RESULTS

Yaw-Free Tests

The results of tests with the model free to yaw are shown in table II. The trim angle of sideslip was, in general, proportional to the rudder deflection at small angles of attack. The effectiveness of the rudder in producing sideslip, however, decreased greatly as the angle of attack increased, whereas the effect of aileron setting became more pronounced. Oscillations were observed in some cases at small angles of attack but the magnitude of these oscillations were not large, being of the order of $\pm 2^{\circ}$. At the largest angle of attack tested, however, (54°) rather large yawing oscillations ($\pm 20^{\circ}$) occurred for almost all control settings. Photographs of the model oscillating are shown in figure 3.

Pitch-Free Tests

The results of tests with the model free to pitch are shown in table III. The model trimmed only at angles of attack within the normal range for all configurations tested. The variation of angle of trim with elevator deflection was normal. The maximum positive value of angle of attack was 16° obtained with 35° up elevator (10° greater than the maximum specified for the airplane). In all cases when the model was displaced from the trimmed position to some large angle of attack, a strong restoring moment brought the model back to the original position of trim with a highly damped oscillation.

DISCUSSION

Some of the data from tables II and III have been compared graphically with data from references 2 and 3 in figures 4 and 5. These figures indicate that, for either of the two test methods (that of the current tests and that of the tests presented in references 2 and 3), the angle of attack for trim does not become large enough to encounter the yawing oscillations obtained in the yaw-free tests at 54° angle of attack. It is interesting to note from these figures that the effectiveness of the rudder and elevator in producing yaw and pitch trim decreases with model scale and Reynolds number, smaller angles of trim being obtained in the current tests.

The test results indicate no unusual tendencies in the longitudinal trim characteristics of this model, the model having trimmed only in the normal range of angles of attack expected for an airplane of conventional design. Insofar as these results and the results of model spin tests (reference 1) indicate trim and spin equilibrium angles of attack well below those for which large yawing oscillations occurred in the yaw-free tests, it appears that no such oscillations as those that were obtained on the airplane would have occurred on the model in its normal range of longitudinal trim unless such oscillations were imposed by control movements. It appears, therefore, that the motions reported for the airplane may have been the direct result of control movements rather than the result of inherent oscillatory tendencies. It appears from the free-spinning tunnel tests of reference 1 that the airplane might be very sensitive to rudder control when in spinning or stalled attitudes and that care should be exercised when moving the rudder in such attitudes to avoid immediately entering a spin in the direction to which the rudder is moved. The undesirable motion encountered during the initial stall tests of the airplane may have been partially due to this sensitivity to rudder control, and, based on table II, partially due to sensitivity to aileron control.

Subsequent to the model tests reported herein and to the airplane stall tests during which difficulty was encountered, additional stall and spin tests have been performed with the same airplane. For these tests the slots previously sealed were operative. No difficulties were encountered during these tests, recovery from the spins and stalls being readily obtained.

CONCLUDING REMARKS

The model test results obtained in the 15-foot free-spinning tunnel on a $\frac{1}{20}$-scale model of the Fleetwings XBTK-1 airplane indicated that large yawing oscillations are obtainable at high angles of attack but such oscillations probably would not occur on the airplane in flight because as indicated by pitch trim tests the airplane could not be trimmed to the angle of attack required. It appears, therefore, that the oscillatory motions reported for the airplane may have been the direct result of control movements rather than the result of inherent oscillatory tendencies.

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1. Wood, John H., and Wilkes, L. Faye: Free-Spinning Tunnel Tests of a $\frac{1}{20}$-Scale Model of the Fleetwings XBTK-1 Airplane - TED No. NACA 2350. NACA MR No. L5L12, Bur. Aero., 1946.

2. Weil, Joseph, and Boykin, Rebecca I.: Wind-Tunnel Tests of the 0.15-Scale Powered Model of the Fleetwings XBTK-1 Airplane. I - Longitudinal Stability and Control - TED No. NACA 2332. NACA MR No. L5D27a, Bur. Aero., 1945.

3. Goodson, Kenneth W., and Silvers, H. Norman: Wind-Tunnel Tests of the 0.15-Scale Powered Model of the Fleetwings XBTK-1 Airplane. III - Lateral Stability and Control - TED No. NACA 2332. NACA MR No. L5F20, Bur. Aero., 1945.

TABLE I

DIMENSIONAL CHARACTERISTICS OF THE

FLEETWINGS XBTK-1 AIRPLANE

Length over all, ft	38.88
Propeller diameter, ft	13.58
Propeller, number of blades	4
Wing:	
Span, ft	48.67
Area, sq ft	380.00
Section, root	NACA 2416
Section, tip	NACA 4412
Incidence:	
Root, deg	2.00
Dihedral break, deg	2.00
Tip, deg	-0.25
Aspect ratio	6.2
Dihedral:	
Center section, deg	0
Outer panels, deg	8° 15'
Mean aerodynamic chord, in.	98.04
Leading edge of mean aerodynamic chord rearward of leading edge of wing, in.	5.98
Ailerons:	
Total area, sq ft	38.00
Hinge line to T. E., percent of chord	20
Span, percent of wing span	53
Landing flaps:	
Total area, sq ft	42
Span, percent wing span	42
Horizontal tail surfaces:	
Total area, sq ft	80.00
Span, ft	18.50
Elevator area, sq ft	26.96
Distance from normal center of gravity to the elevator hinge line, ft	21.90
Vertical tail surfaces:	
Total area, sq ft	51.25
Total rudder area, sq ft	14.48
Dorsal fin area, sq ft	12.25
Distance from normal center of gravity to rudder hinge line, ft	23.60

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TABLE II

YAW TRIM TESTS OF A $\frac{1}{20}$-SCALE MODEL OF THE FLEETWINGS XBTK-1 AIRPLANE

[Center of gravity 27.8 percent $\bar{c}$, flaps neutral; cockpit closed; external stores removed; model free to yaw about stability Z-axis]

α (deg)	δ_r (deg)	δ_e (deg)	δ_a (deg)	Trim ψ (deg)
0	0	0	0	6
↓	10	0	0	-8
	20	0	0	-10
	30	0	0	-10
	30	15	0	-10
	30	-25	0	-9
	30	-25	±15L	-9
	30	-25	±15R	-9
	30	-25	Both 5 up	-9
10	0	0	0	1
↓	10	0	0	-5
	20	0	0	-9
	30	0	0	-6
	30	15	0	-6
	30	-25	0	-6
	30	-25	±15L	-3
	30	-25	±15R	-10
20	0	0	0	2
↓	10	0	0	1
	20	0	0	-1
	30	0	0	-2
	30	15	0	1 to -1
	30	-25	0	
	30	-25	±15L	0 to 5
	30	-25	±15R	-3
30	0	0	0	2
↓	10	0	0	1
	20	0	0	-1
	30	0	0	-1
	30	15	0	0
	30	-25	0	0
	30	-25	±15L	4
	30	-25	±15R	-4

L stick left.
R stick right.

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TABLE II - Concluded

YAW TRIM TESTS OF A $\frac{1}{20}$-SCALE MODEL - Concluded

[Center of gravity 27.8 percent $\bar{c}$, flaps neutral; cockpit closed; external stores removed; model free to yaw about stability Z-axis]

α (deg)	δ_r (deg)	δ_e (deg)	δ_a (deg)	Trim ψ (deg)
40	0	0	0	3
↓	10	0	0	2
↓	20	0	0	1
↓	30	0	0	2
↓	30	15	0	2
↓	30	-25	0	0 to 2
↓	30	-25	±15L	7
↓	30	-25	±15R	-6
54	0	0	0	20 to -18
↓	10	0	0	17 to -12
↓	20	0	0	19 to -17
↓	30	0	0	17 to -20
↓	-30	0	0	16 to -11
↓	-20	0	0	20 to -16
↓	-10	0	0	19 to -15
↓	30	15	0	-11 to -21
↓	30	-25	0	18 to -22
↓	30	-25	±15L	21 to -12
↓	30	-25	±15R	0 to 5
↓	30	-25	Both 5 up	20 to -20
↓	30	0	±15L	23 to -24
↓	30	0	±15R	23 to -21
↓	0	0	±15L	19 to -6
↓	0	0	±15R	13 to -19

L stick left.
R stick right.

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TABLE III

PITCH TRIM TESTS OF A $\frac{1}{20}$-SCALE MODEL OF THE FLEETWINGS XBTK-1 AIRPLANE

[Center of gravity 27.8 percent $\bar{c}$; flaps neutral; cockpit closed; external stores removed; model free to pitch about stability Y-axis]

ψ (deg)	δ_e (deg)	δ_r (deg)	δ_a (deg)	Trim α (deg)
0	20	0	0	-13
	15	0	0	-12
	0	0	0	-4
	-10	0	0	2
	-25	0	0	13
	-35	0	0	13
	0	0	±15L	-8
	0	0	±15R	-8
	0	0	Both 5 up	-5
	0	10	0	-8
	0	20	0	-7
	0	30	0	-8
	0	-30	0	-7
19	20	0	0	-21
	15	0	0	-21
	0	0	0	-14
	-10	0	0	-5
	-25	0	0	9
	-35	0	0	11
	-25	30	0	11
	-25	-30	0	11
	0	0	±15L	-16
	0	0	±15R	-13
	0	0	Both 5 up	-14
-18	20	0	0	-16
	15	0	0	-16
	0	0	0	-7
	-10	0	0	5
	-25	0	0	14
	-35	0	0	16

L stick left.
R stick right.

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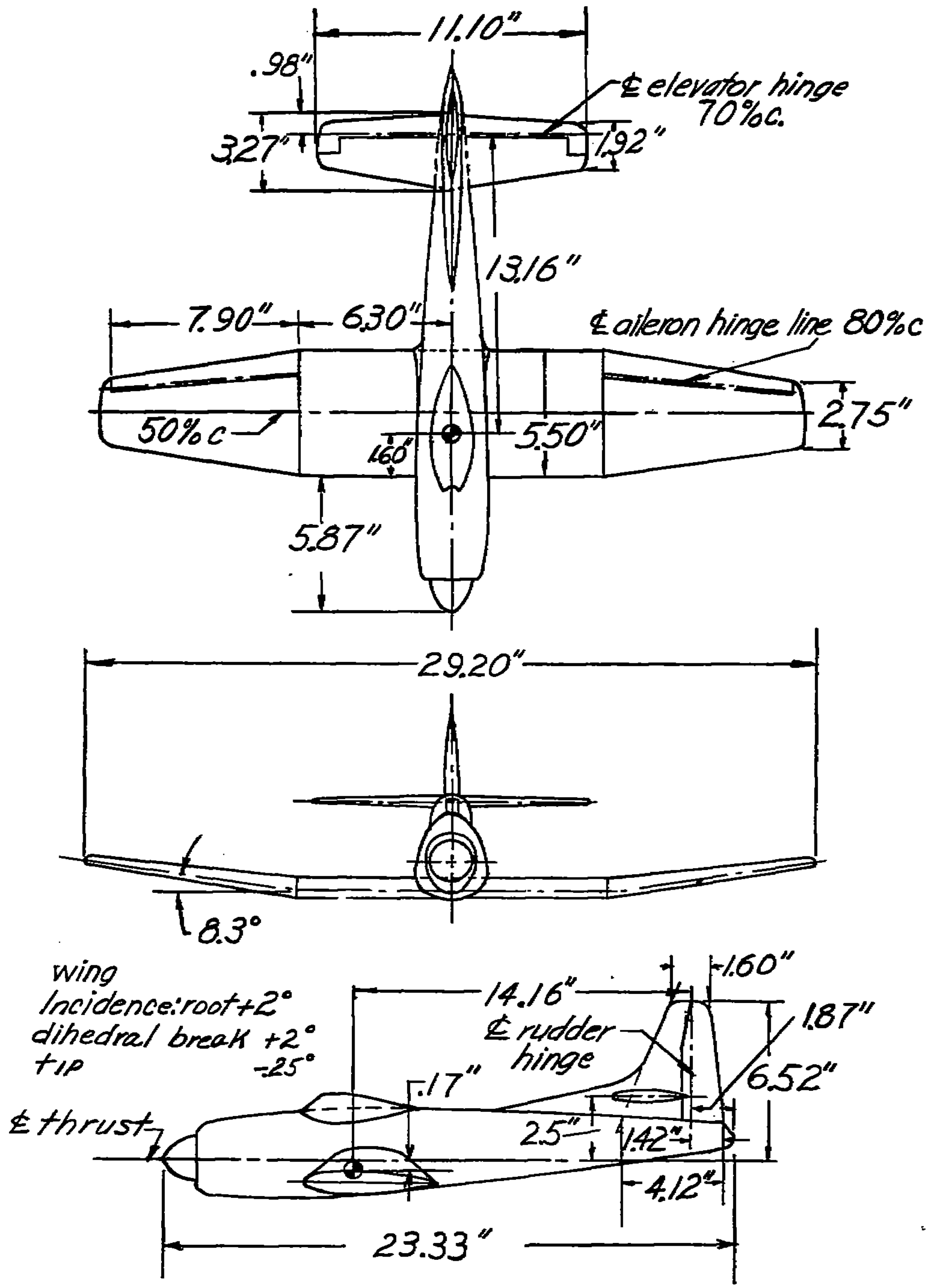

Figure 1.- Three-view drawing of the 1/20-scale model of the Fleetwings XBTK-1 airplane. Center-of-gravity shown for scout loading.

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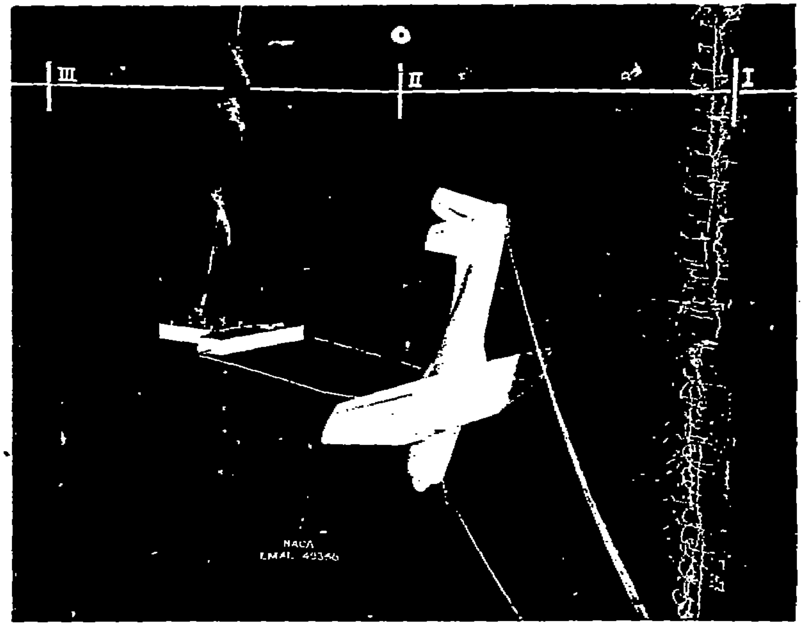

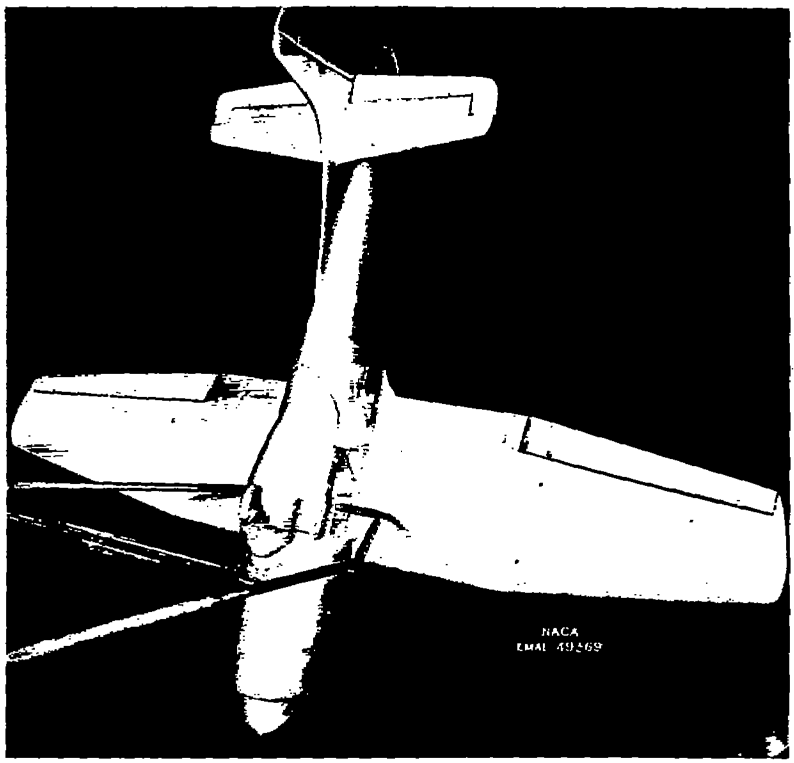

Figure 2.- Photographs of the $\frac{1}{20}$-scale model of the Fleetwings XBTK-1 airplane mounted free to pitch in the 15-foot free-spinning tunnel.

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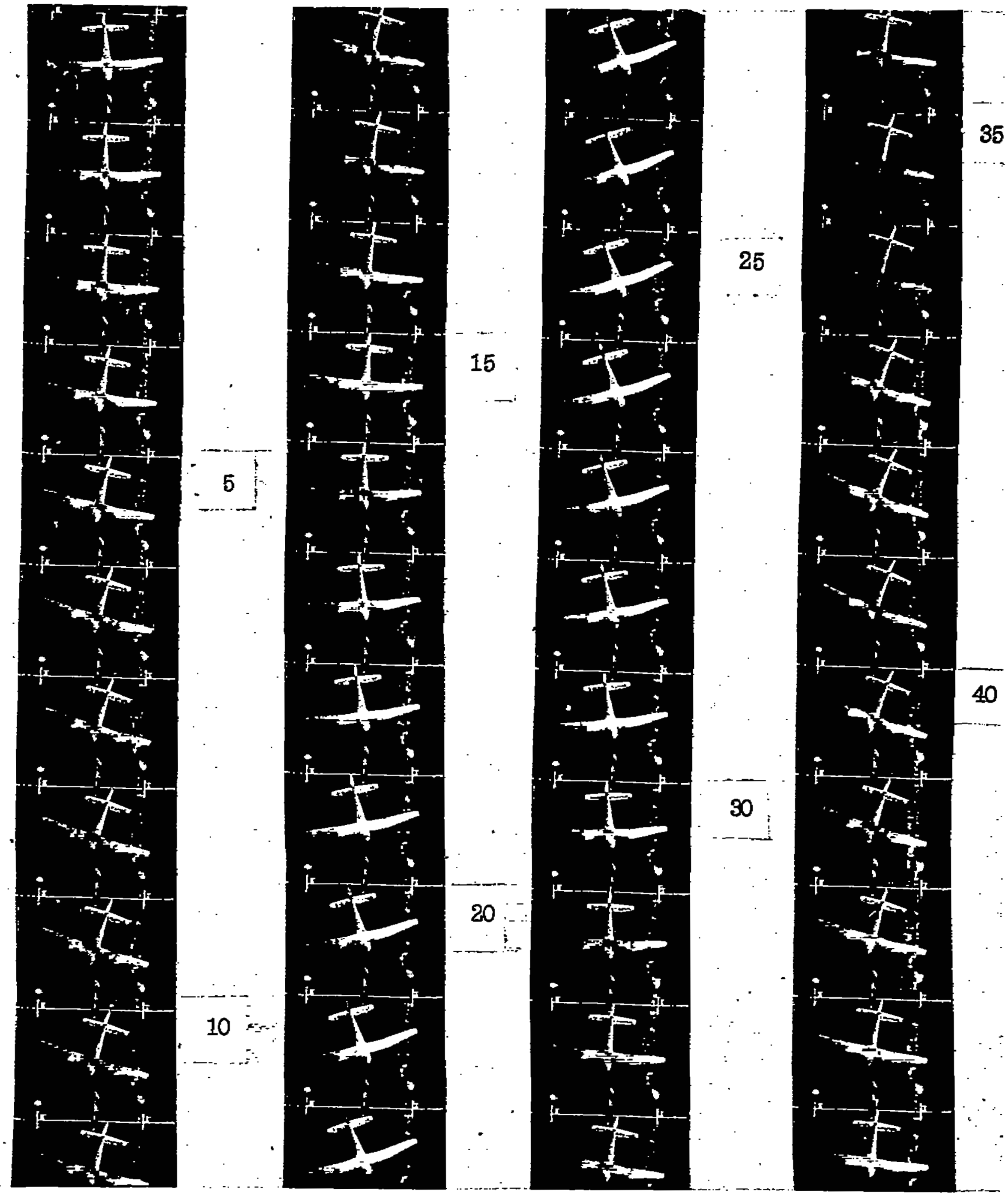

Figure 3.- Typical motion of the $\frac{1}{20}$-scale model of the XBTK-1 airplane when mounted free to yaw at $\alpha = 54^{\circ}$. Camera speed 32 frames per second.

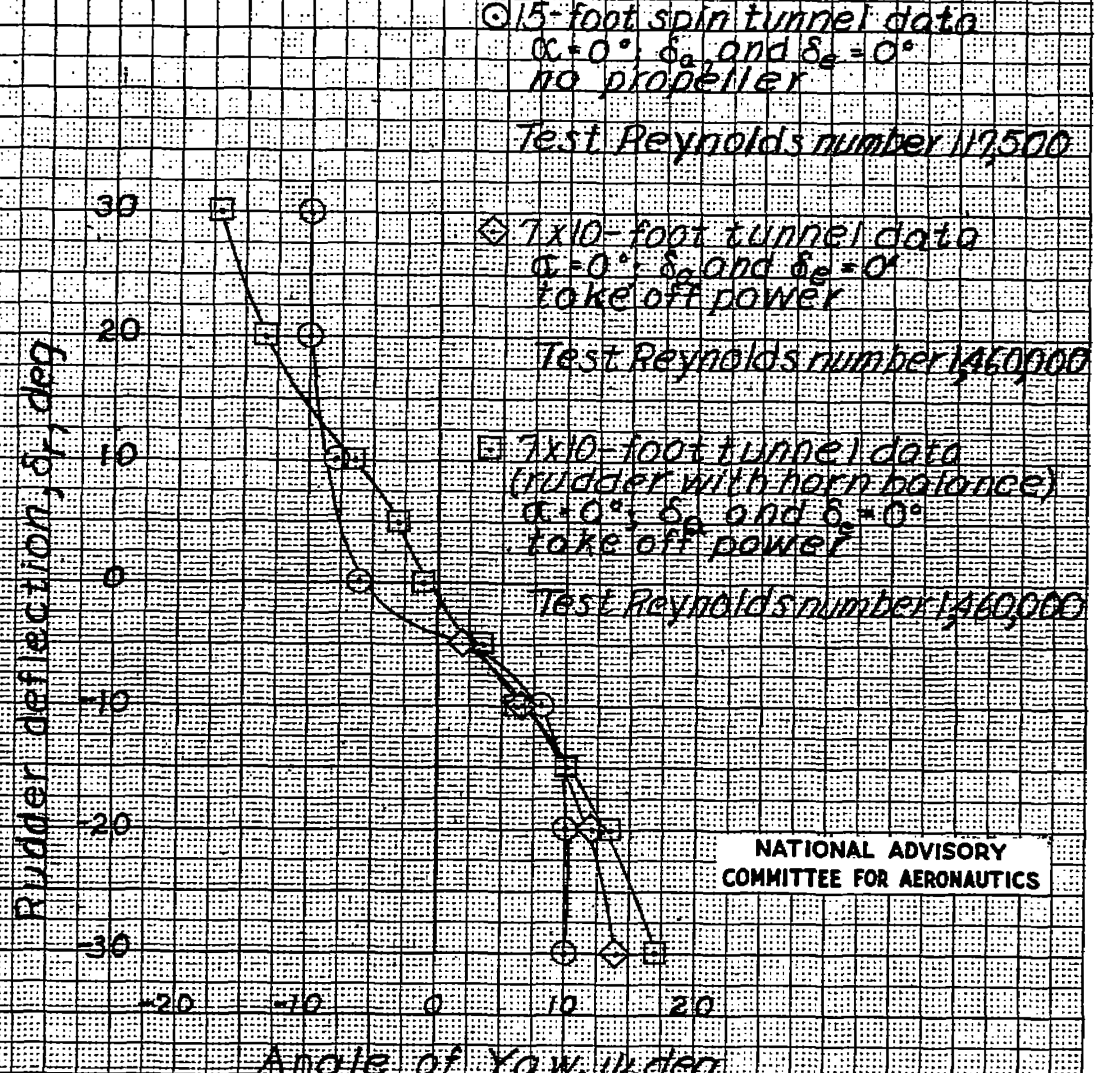

Figure 4.– Effect of rudder deflection upon yaw trim characteristics of models of the XBTK-1 airplane

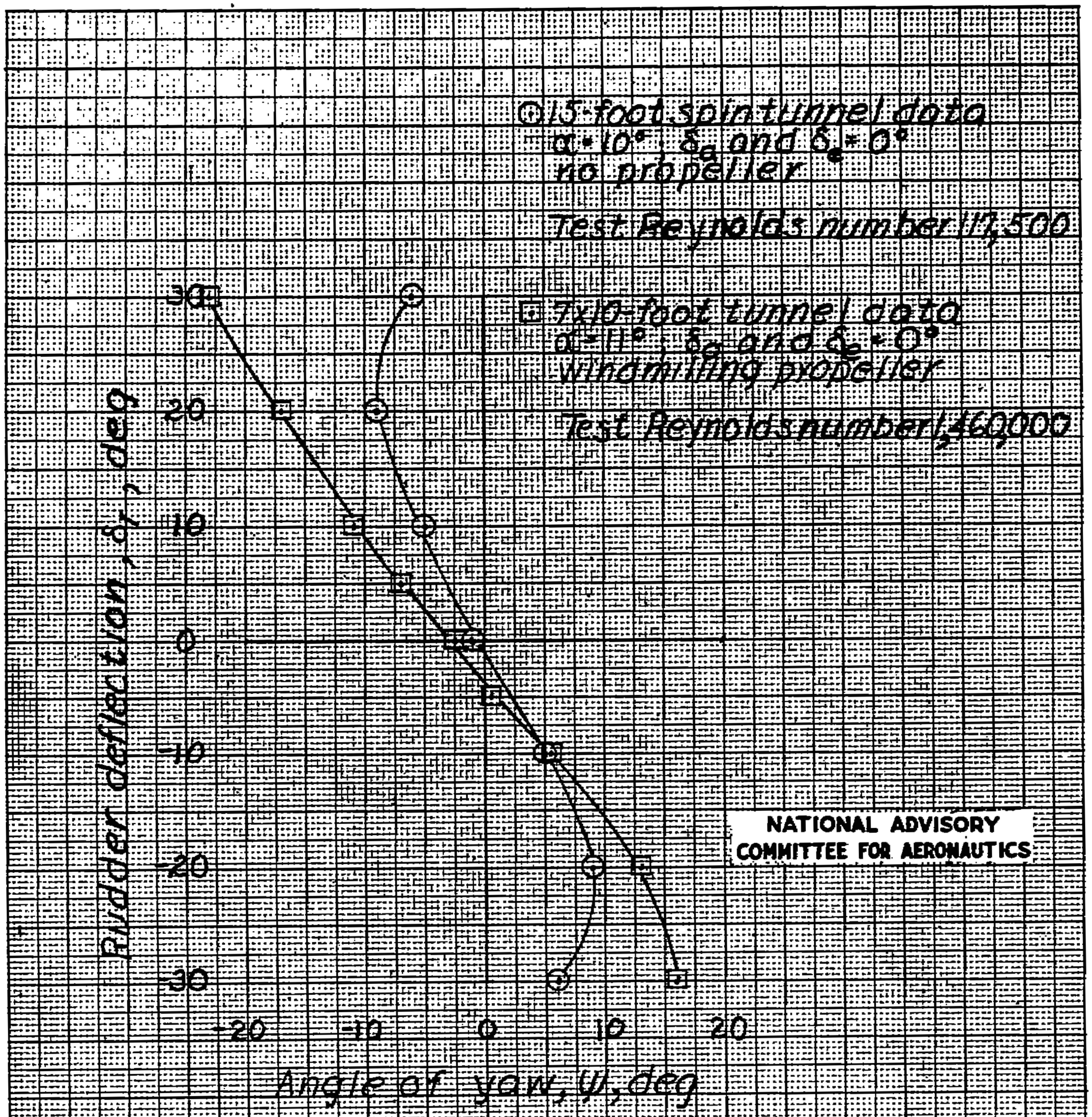

Figure 4.- concluded

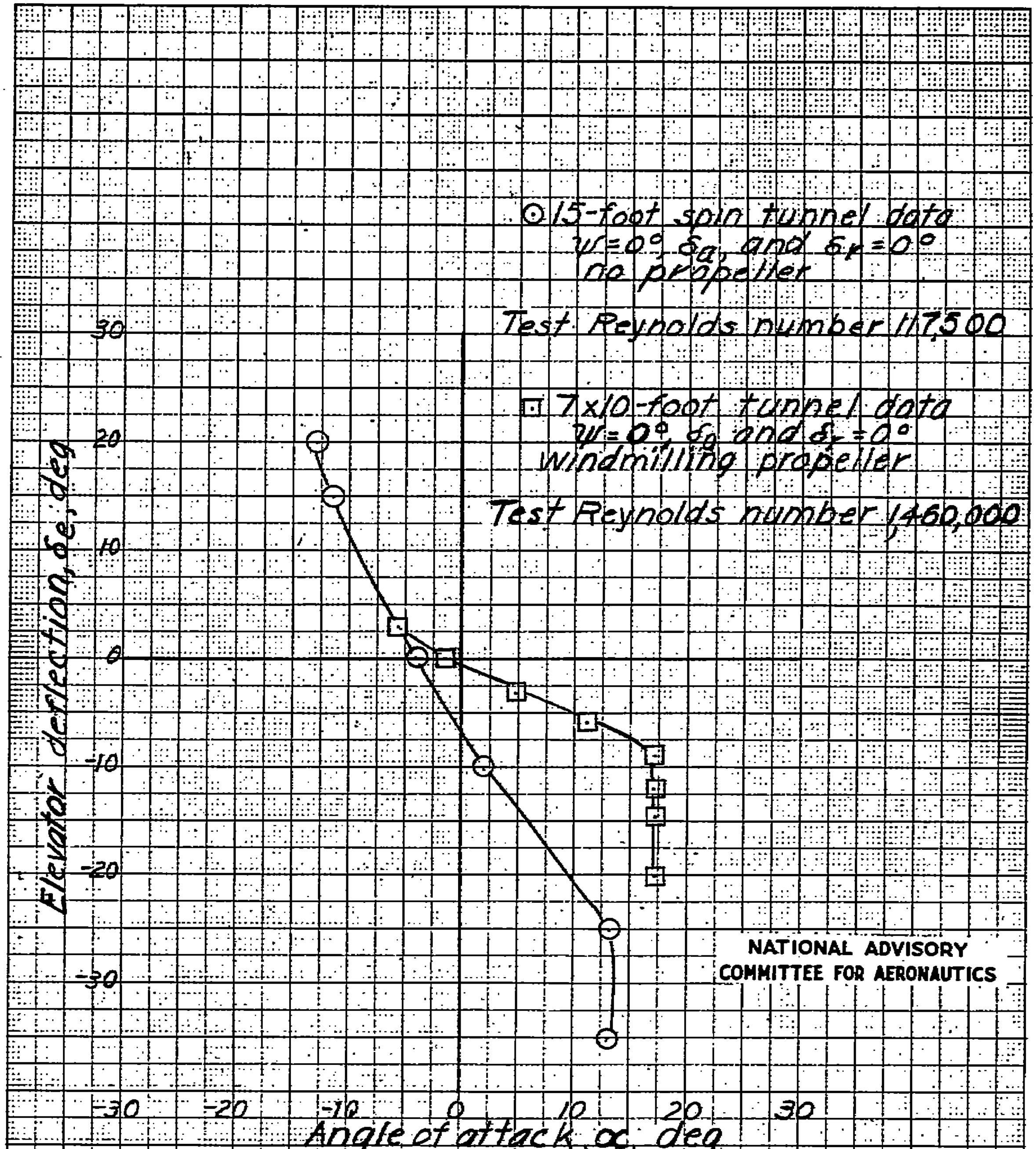

Figure 5.- Effect of elevator deflection upon pitch trim characteristics of models of the XBTK-1 airplane.